

8.4 A COMPARISON OF THE AUTOMATED METEOROLOGICAL PROFILING SYSTEM HIGH RESOLUTION FLIGHT ELEMENT TO THE KENNEDY SPACE CENTER 50MHz DOPPLER WIND PROFILER

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1. INTRODUCTION

Wind profile measurement and the simulation of aerodynamic loads on a launch vehicle play an important role in determining launch capability and post launch assessment of the vehicle's performance. To date, all United States range certified wind profile measurement systems have been based on balloon tracking. Since the 1960's, the standard used by the National Aeronautics and Space Administration and the Air Force at the Cape Canaveral Air Station (CCAS) for detailed wind profile measurements has been the radar tracked, aerodynamically stabilized Jimsphere balloon system (Wilfong et al., 1997).

Currently, the Air Force is nearing certification and operational implementation of the Automated Meteorological Profiling System (AMPS) at CCAS and Vandenberg Air Force Base (VAFB). AMPS uses the Global Positioning System for tracking the Jimsphere balloon. It is anticipated that the AMPS/Jimsphere, named the High Resolution Flight Element (HRFE), will have equivalent, or better resolution than the radar tracked Jimsphere, especially when the balloon is far downrange, at a low elevation angle.

By the 1980's, the development of Doppler Wind Profilers (DWP) had become sufficiently advanced to justify an experimental measurement program at Kennedy Space Center (KSC). In 1989 a 50 MHz DWP was installed at KSC. In principal, the 50 MHz DWP has the capability to track the evolution of wind profile dynamics within 5 minutes of a launch. Because of fundamental differences in the measurement technique, there is a significant time and space differential between 50 MHz DWP and HRFE wind profiles. This paper describes a study to quantify these differences from a sample of 50 MHz DWP/HRFE pairs obtained during the AMPS certification test program.

2. DATA DESCRIPTION

The AMPS HRFE typically rises to a minimum of 16.5 km, before it starts floating. The HRFE is required to have a mean vertical resolution ≤ 122 m and a RMS velocity error in the horizontal wind component ≤ 1.5 m/s. Based on early results from AMPS testing, the HRFE will easily meet these requirements.

The 50 MHz DWP is located 15 km from the AMPS ground station, next to the Space Shuttle landing facility at KSC. It produces wind profiles from an altitude of 2 km to 18.6 km every 5 minutes using the Median Filter/First-Guess (MFFG) algorithm (Schumann et al. 1999). Wind speed and direction are derived for 112 gates, spaced 150 m apart. A recent study by Merceret (1999), indicates that the vertical resolution of the 50 MHz DWP is in the range of two to three times larger than the HRFE. An identical 50 MHz DWP is currently being installed at VAFB.

For this study, AMPS HRFE profiles were examined during the period from September 1999 through April 2000. HRFE profiles that were selected reached a minimum altitude of 16.5 km, and were of good quality, with only a small number having missing wind data. Unfortunately, during this time the profiler was down for extended periods, primarily for repairs due to damage incurred during hurricane Irene. This limited the number of available HRFE/profiler pairs to 30 (Table 1).

Noise, due to strong ground returns in most of the 50 MHz DWP wind profiles near the surface, required omission of gates 1 through 27. Gate 28 is at an altitude of 6.1 km. A maximum height of 16.6 km was used for the study, since all but three of the HRFE profiles reached at least 16.6 km. Also, a lower profiler signal-to-noise ratio caused much more erroneous data above this height. A height of 16.6 km corresponds to gate 98 on the profiler.

An example of the u and v components from a HRFE/profiler pair is shown in Figure 1. Each 50 MHz DWP profile was selected 30 min after the launch of the HRFE element. This puts the 50 MHz DWP profile time close to the median time it takes the HRFE to attain its maximum altitude, and reduces the spatial difference between the profiler and the HRFE. A comparison of the u and v component of each gate of the profiler was made to the HRFE. The HRFE u and v components were averaged over a 150 m height increments to match the height increment of each profiler gate.

Since the raw spectral data from each of the three beams of the profiler are not archived, only the spectral moment data is available from the 50 MHz DWP. It is important to note that during a launch countdown, the spectral data from the profiler is manually quality controlled by adjusting parameters of the MFFG algorithm. The 50 MHz DWP profiles used in this study were not manually quality controlled in this manner. As a result, obvious inaccurate wind data, caused by erroneous spikes and/or side lobe returns, was present in many of the 50 MHz DWP profiles. Without the raw spectral data, it is impossible to go back and accurately

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correct the erroneous data, as is done during launch countdowns.

Because of the small number of HRFE/profiler pairs, and in order to retain a statistically significant data set, post quality control of the profiler data was not performed for this study.

3. RESULTS

The root mean square (RMS) difference between the u and v components of the HRFE minus the 50 MHz DWP for each HRFE/profiler pair is shown in Table 1. The RMS differences varied widely for the 30 pairs. The large RMS differences were due primarily to the presence of obvious inaccurate winds calculated by the MFFG algorithm extending over several gates.

Figure 2 shows the mean difference, and the mean absolute difference, versus height, between the u and v components of the HRFE minus the 50 MHz DWP. Above 9 km, the u component mean differences are slightly positive, while the v component deviations are negative, but to a much lesser magnitude. The average of the mean difference for each gate from 9 km to 16.6 km for the u component is 1.13 m/s, and -0.80 for the v component. This tends to indicate that the HRFE gives a slightly higher westerly wind component and a less northerly wind component than the profiler.

The mean absolute difference shows a large difference in the magnitude of the u and v wind components near 6.5 km, 9 km, 12.5 km, and above 14.5 km. These were regions where the MFFG was prone to give inaccurate wind data. The erroneous winds at 6.5 and 9 km are likely caused by ground returns due to atmospheric inversions. At 12.5 km, the errors may be a combination of persistent high wind speeds and an atmospheric inversion at the tropopause. The erroneous winds above 14.5 km are likely due to weak signal returns, and thus a low signal to noise ratio.

For the 30 HRFE/profiler pairs, the root mean square (RMS) difference was calculated between the u and v components of the HRFE minus the 50 MHz DWP for each profiler gate (Figure 3). It can be seen that there is a large RMS value in both components between 6 and 7 km. This is primarily due to four 50 MHz DWP profiles where there were inaccurate velocities selected by the MFFG. By removing these four HRFE/profiler pairs, with RMS difference values > 8.0 , the variability in the component RMS differences is reduced (Figure 4). The results indicate no pronounced trends in the RMS differences with respect to height, unlike an earlier

study by Schumann, et al. (1999) that indicated a tendency for the RMS values to increase with height. This may be because no quality control was done on the MFFG derived profiles, and the HRFE should exhibit improved accuracy at higher altitudes than with radar tracked Jimspheres used in the previous study.

4. CONCLUSION

The 50MHz DWP offers promise for future use in the aerospace community. However, more work needs to be done to improve MFFG algorithm such that human quality control is not needed during launch countdown support.

The authors suggest taking this study further by removing the time dependence, thus isolating the spatial variation. This will require matching each five minute 50 MHz DWP profile during the HRFE ascent to the corresponding HRFE height increment during that 5 min period. Also, a method could be developed to automate correction of obvious erroneous profiler wind data to simulate human quality control of the spectral data.

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Table 1. AMPS HRFE Flight Identification number, date and time, and 50 MHz profiler times

Sample Number	Date	AMPS Flight ID	AMPS File ID	AMPS Launch Time (UTC)	50 MHz DWP Time (UTC)	U Wind Comp. RMS Diff. (m/s)	V Wind Comp. RMS Diff. (m/s)
1	7 Sept 99	250B	CC3250B	16:12	16:42	1.68	2.37
2	7 Sept 99	250D	CC1250D	18:39	19:08	1.88	1.40
3	8 Sept 99	251C	CC5251C	14:12	14:41	1.54	1.51
4	8 Sept 99	251D	CC6251D	15:58	16:27	1.49	1.17
5	8 Sept 99	251E	CC1251E	18:03	18:33	1.85	2.32
6	9 Sept 99	252C	CC5252C	14:36	15:05	1.75	1.93
7	30 Sept 99	273C	CC2273C	17:00	17:32	3.36	3.56
8	8 Oct 99	281A	CC1281A	15:07	15:37	5.29	4.44
9	14 Oct 99	287A	CC3287A	13:35	14:04	1.78	1.61
10	3 Nov 99	307A	CC4307A	14:55	15:02	2.91	2.74
11	3 Nov 99	307C	CC4397C	17:00	17:13	2.73	2.56
12	9 Nov 99	313A	CC3313A	14:30	15:02	5.57	5.34
13	9 Nov 99	313E	CC1313E	16:42	17:13	6.24	5.58
14	30 Nov 99	334A	CC1334A	15:15	15:43	3.00	3.79
15	30 Nov 99	334C	CC5334C	17:05	17:33	3.64	3.34
16	1 Dec 99	335C	CC1335C	16:45	17:13	5.32	5.47
17	2 Dec 99	336D	CC5336D	16:02	16:33	3.57	4.23
18	6 Dec 99	340A	CC1340A	14:15	14:46	6.51	7.38
19	6 Dec 99	340C	CC5340C	16:30	17:02	6.07	6.24
20	6 Dec 99	340E	CC3340E	18:30	19:02	6.98	7.53
21	14 Dec 99	348B	CC5348B	16:20	16:52	13.99	13.19
22	12 Jan 00	012C	CC5012C	17:07	17:38	1.72	1.85
23	21 Jan 00	021C	CC1021C	16:40	17:12	1.32	1.98
24	26 Jan 00	026A	CC1026A	15:00	15:31	3.07	4.32
25	27 Jan 00	027D	CC3027D	17:15	17:42	1.55	1.63
26	28 Jan 00	028A	CC3028A	14:30	15:01	1.94	2.55
27	2 Feb 00	032B	CC3032B	14:16	14:47	9.96	8.02
28	2 Feb 00	032C	CC3032C	16:22	16:52	9.82	9.78
29	23 Feb 00	054A	CC1054A	18:15	18:43	8.45	8.28
30	24 Feb 00	055A	CC5055A	18:00	18:13	1.61	2.07

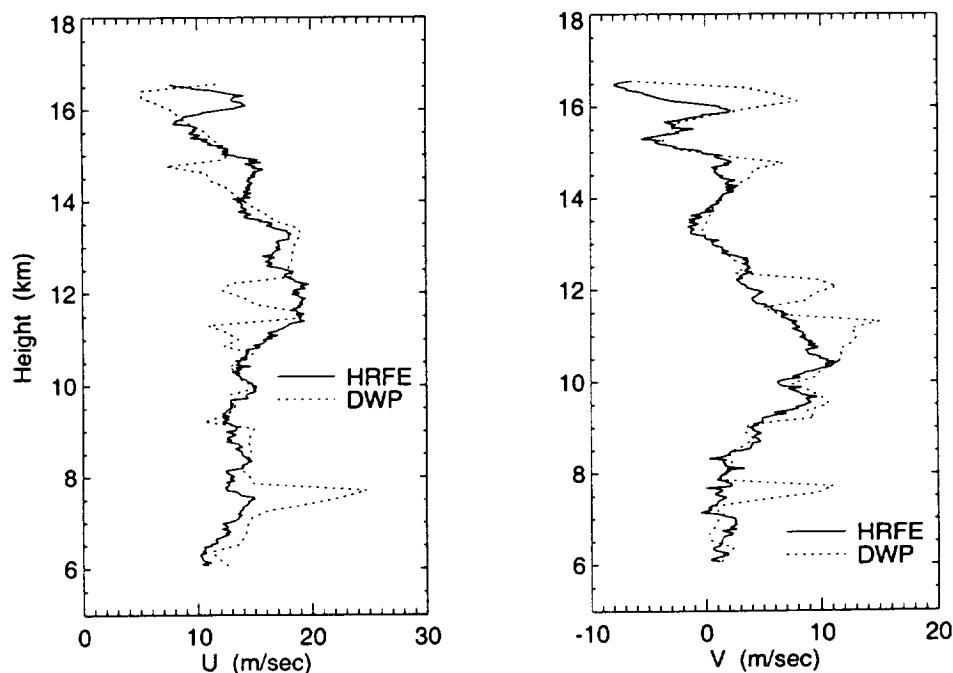


Figure 1. A plot of the u and v component HRFE (17:00 UTC)/ 50 MHz DWP (17:32 UTC) wind profile pair made on 30 September 1999.

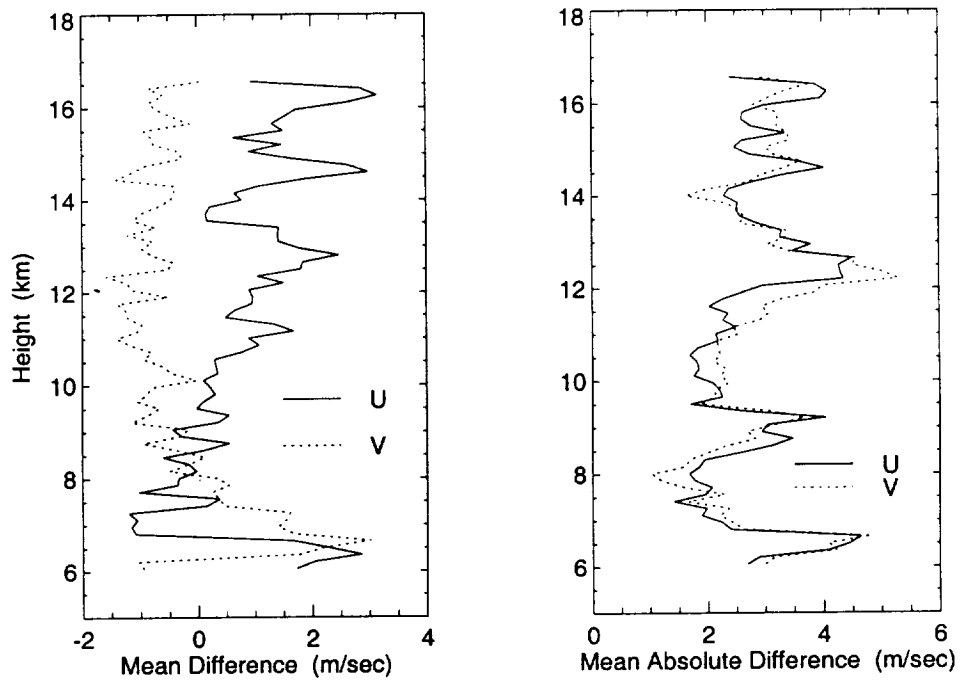


Figure 2. A plot of the mean difference and the mean absolute difference between the u and v components (HRFE - 50 MHz DWP) of the 30 pairs.

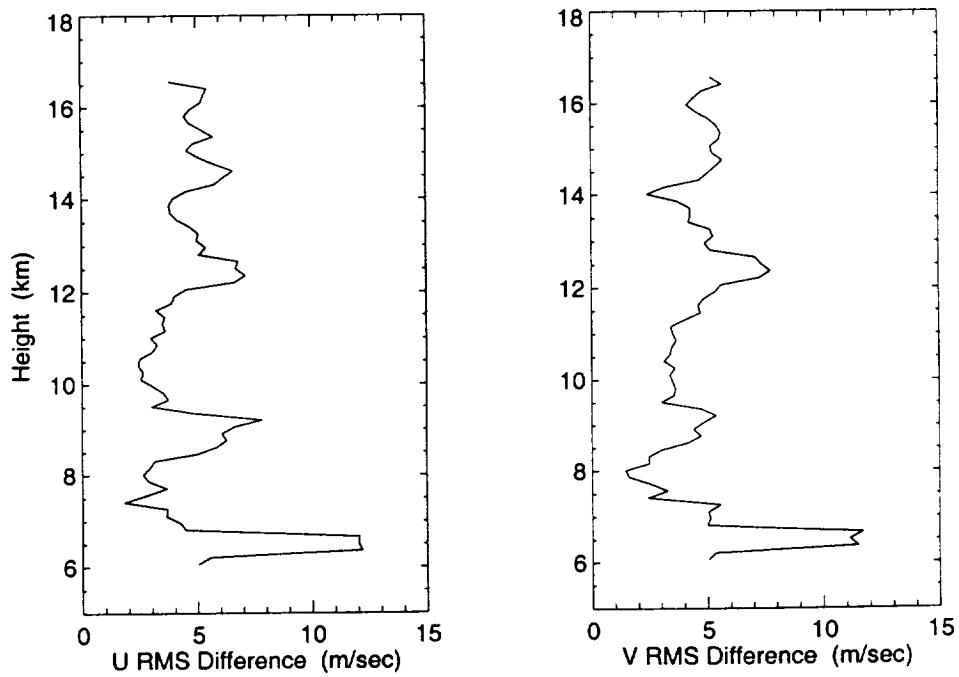


Figure 3. A plot of the root mean square difference between the u and v components (HRFE - 50 MHz DWP) of the 30 pairs.

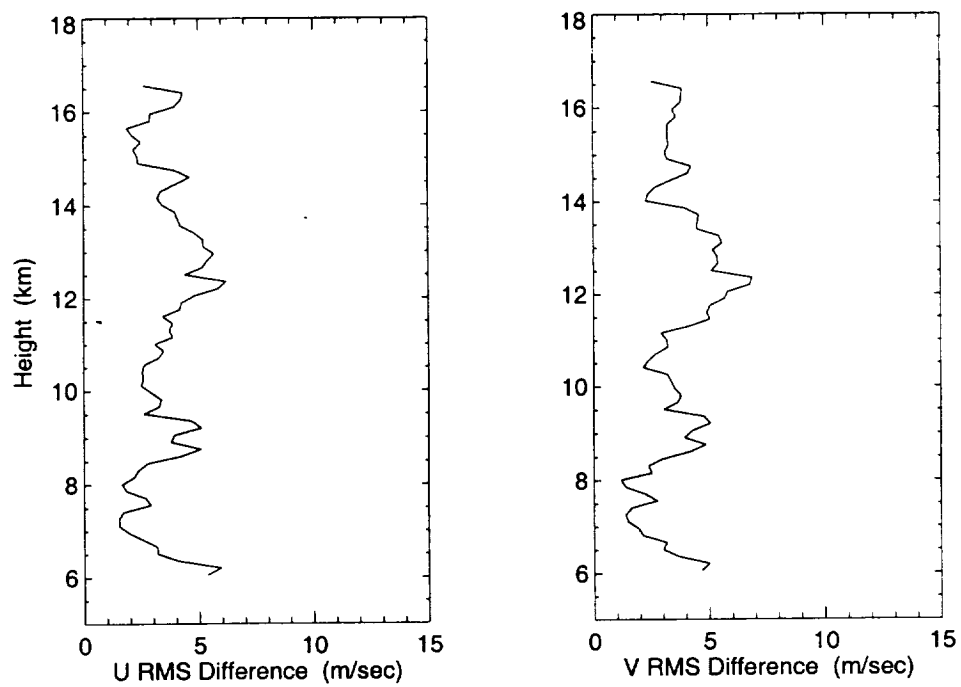


Figure 4. A plot of the root mean square difference between the u and v components (HRFE - 50 MHz DWP) of 26 pairs.